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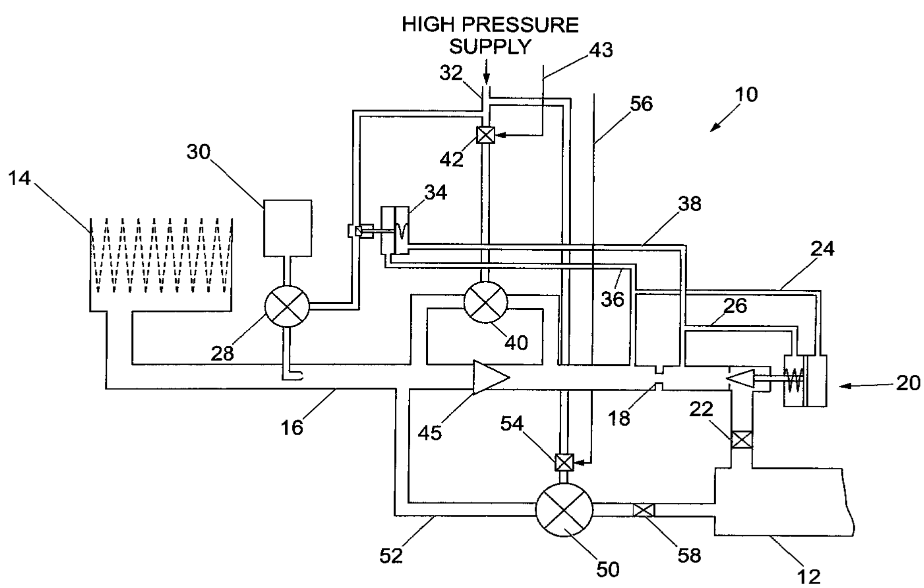
(54) Title: APPARATUS FOR AND METHOD OF FLOODING AND/OR PRESSURE TESTING PIPELINES



(57) Abstract: Apparatus for and methods of flooding and/or pressure testing a pipe (12) or facility, wherein a subsea device (50) is used to pressure test the pipe (12) once flooded. The subsea device is typically a pump (50) that is located subsea, and preferably supplied from a local power supply (e.g. batteries, ROV, AUV etc). Certain embodiments allow the pipe (12) to be flooded and then pressure tested in consecutive operations without having to de-couple and/or couple additional apparatus to the pipe (12).

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"Apparatus for and Method of Flooding and/or Pressure Testing Pipelines"

The present invention provides apparatus and methods for flooding of pipelines or facilities, and more particularly, but not exclusively, to pressure testing (also called hydro or leak testing) of the pipeline or facility once flooded.

It is conventional to flood subsea pipelines that are normally air- or gas-filled when they are initially laid on the seabed, typically from a lay barge or vessel. As the pipeline is air- or gas-filled, it is generally light and can be affected by storms, tides or currents that can move the pipeline. This can cause damage to the pipeline and the pipeline is generally flooded to make it heavier and thus less susceptible to tides, currents and storms.

There are a number of ways in which to flood a pipeline, and it is typically done by pumping water (e.g. seawater) into one end of the pipeline in order to drive a pig through it. The conventional method typically uses a surface vessel or surface installation from which extends a large-bore, high-pressure pipe or hose to carry the high-pressure flow of water to the pipeline on the seabed. The surface vessel must also be equipped with a relatively large pump of considerable horsepower, all of which increase the costs involved in this operation, particularly as the vessel must remain *in situ* during the flooding of the pipeline.

Once the pipeline has been flooded, it is desirable to pressure test it to ensure that there are no leaks and that it can withstand high pressures. This generally involves the use of a pump on the surface vessel that supplies water at high pressure to the pipeline to increase the internal pressure therein to a predetermined level. The pressure is then held at this level for a period of time, typically for around 24 hours. The surface vessel typically remains *in situ* during the pressure test to monitor the status of the pipeline, and this can add significant costs to the operation.

It is to be understood that certain embodiments of the present invention can be used to pressure test a pipeline or facility that has previously been flooded using any conventional method.

According to a first aspect of the present invention, there is provided apparatus for pressure testing a pipe or facility, the apparatus comprising an inlet having an opening to admit fluid into the pipe or facility, a flow control device to control the flow rate of fluid into the pipe or facility, and a subsea device to supply a pressurised fluid at high pressure into the pipe or facility.

According to a second aspect of the present invention, there is provided a method of pressure testing a pipe or facility, the method comprising the steps of admitting fluid into the pipe or facility to flood it, introducing a pressurised fluid into the pipe or facility, and monitoring the retention of fluid within the pipe or facility.

The invention also provides apparatus for pressure testing a subsea pipe or facility, the apparatus comprising a subsea device for introducing a pressurised fluid into the pipe or facility at high pressure.

The invention further provides a method of pressure testing a subsea pipe or facility, the method comprising the step of actuating a subsea device to introduce a pressurised fluid into the pipe or facility at high pressure.

In certain embodiments, the method includes the additional step of providing a subsea device. The method typically includes the additional step of coupling the subsea device to the pipe or facility. This can be done at the surface or subsea.

The pressurised fluid is typically pressurised seawater, but may be a gas (e.g. air) or any other suitable fluid. The fluid is typically water (e.g. seawater).

The subsea device is typically capable of providing high pressures, typically at low flow rates.

The subsea device typically comprises a pump. The pump is preferably a high-pressure, low-flow rate pump. The pump is typically electrically operated, and can be coupled to an electrical supply from, for example, a surface vessel or installation. It will be appreciated that it is relatively simple to drop an electrical cable to the seabed when compared with relatively large-bore conduits that are capable of carrying high-pressure fluids.

Alternatively, the pump could be hydraulically operated, and can be coupled to a hydraulic fluid supply from, for example a surface vessel or installation. Again, it is relatively simple to drop a relatively small-bore hydraulic hose from the surface to the seabed when compared with a relatively large-bore conduit.

However, the pump is preferably supplied by a local power supply. This provides the advantage that an electrical cable or hydraulic hose is not required to be dropped from a support vessel. The local power supply can be a battery or a bank of batteries. The battery or batteries can be charged using an alternator or the like that is typically coupled into the inlet. The alternator can include a turbine or the like, where the turbine is driven by the flow of fluid through the inlet. Thus, the flow of fluid drives the turbine and thus the alternator to charge the battery or batteries.

Alternatively, the local power supply may comprise an electrical or other (e.g. hydraulic or pneumatic) power supply from a remotely operated vehicle (ROV) or autonomous vehicle (AUV).

As a further alternative, the pump can be hydraulically or pneumatically powered using an appropriate power source.

As a further alternative, the subsea device may comprise one or more gas bottles or any other supply of pressurised fluid, where the bottles are typically capable of providing a high-pressure, low-flow gas into a reservoir or other container of fluids (e.g. seawater). The gas bottle(s) typically admit pressurised gas into the reservoir and force pressurised fluid into the pipe or facility that is being pressure tested. The gas bottles are typically coupled *via* a regulating device that controls the flow of gas into the reservoir and thus the flow of pressurised fluid into the pipe or facility. The regulating device may comprise a remotely operated valve for example. Thus, the flow of gas into the reservoir causes a flow of fluids into the pipe or facility that can be used to pressure test it.

The inlet is typically coupled to the pipe *via* a pipe inlet port, and can be coupled underwater to the inlet port by a diver, ROV or AUV. The inlet can be coupled to the facility using any conventional means.

The apparatus typically includes a flow-recording device for measuring and/or recording the flow of fluid entering the pipe or facility. The flow-recording device is typically located in the inlet, but may be located at any convenient location. The flow recording device can be a dial that is coupled into the inlet and can be read using an underwater camera on an ROV for example. Alternatively, the flow-recording device may be electrically or otherwise coupled (e.g. *via* a telemetry system) to the surface for remote monitoring.

The inlet typically includes an isolating valve that can be opened and closed to admit or restrict fluid flow into the pipe or facility.

The flow control device typically comprises a variable opening valve that can be remotely or locally operated (e.g. in response to changes in fluid pressure) to maintain a substantially constant flow of fluid into the pipe or facility.

The inlet preferably contains a filter that can be used to filter or strain the fluid that is admitted into the pipe or facility. Optionally, the apparatus may include a chemical injection device for injecting chemicals into the fluid entering the pipe or facility. The chemical injection device typically comprises a pump that is in fluid communication with one or more reservoirs of chemical additives.

The step of admitting fluid into the pipe or facility typically involves opening the isolating valve to allow fluid to flow into the pipe or facility under the head of water above the pipe or facility. That is, the hydrostatic head of water above the pipe or facility is typically used to flood it.

The step of providing fluid into the pipe at high pressure typically involves actuation of the subsea device.

The apparatus, including the subsea device, is typically provided on a single subsea skid. This provides the advantage that the pipe or facility can be flooded and pressure tested without having to couple and de-couple various equipment and apparatus to and from the pipe or facility. However, it will be appreciated that the subsea device may be located on a separate skid, or can be coupled to an ROV or AUV for example.

GB2303895B, the entire disclosure of which is incorporated herein by reference, describes a suitable underwater pipeline apparatus for delivering a pig unit through a seabed pipeline that uses the hydrostatic pressure difference between the inside of the pipeline and the surrounding seawater to admit water into the pipeline in a controlled manner, typically through a flow regulator and a filtration system.

The method preferably includes the additional step of filtering the fluid that enters the pipe or facility.

The method optionally includes the additional step of adding chemicals to the fluid that enters the pipe or facility.

The pipe typically comprises a pipeline, and preferably a subsea pipeline.

Embodiments of the present invention shall now be described, by way of example only, with reference to the accompanying drawing, in which:

Fig. 1 is a schematic representation of an exemplary embodiment of apparatus for flooding and pressure testing a pipeline;

Fig. 2 is a schematic representation of an alternative embodiment of apparatus for flooding and pressure testing a pipeline; and

Fig. 3 is a schematic representation of a pipeline laid on the seabed between two subsea installations.

Referring to the drawings, Fig. 1 shows an embodiment of apparatus 10 for use in flooding and pressure testing (also called hydro or leak testing) a pipeline 12. The pipeline 12 can be of any conventional size and type, and is generally an initially air- or gas-filled pipeline that is laid on the seabed (not shown) in any conventional manner. However, embodiments of the present invention can be used with a pipeline or facility that has previously been flooded using any conventional method. It is also to be noted that embodiments of the present invention will be described with reference to a pipeline, but the invention can be used to flood and/or pressure test other subsea facilities and installations.

Apparatus 10 typically includes an intake filter 14 that is capable of straining the surrounding seawater to remove substantially all of the contaminants before it is allowed to enter the pipeline 12. However, the intake filter 14 need only strain the seawater to the required standard rather than remove substantially all the contaminants. Thus, the intake filter 14 is preferably capable of straining the seawater to the required standard, but is also preferably capable of providing water at a flow rate necessary to flood the pipeline 12.

The intake filter 14 is coupled to the pipeline 12 *via* a conduit 16 that includes an orifice plate 18, a variable choke, generally designated 20, and an isolating valve 22. The variable choke 20 can be used to adjust the flow of water into the pipeline 12 to compensate for the diminishing hydrostatic head that inevitably occurs, for as long as is practicable. The variable choke 20 is automatically controlled in response to the currently existing flow rate by use of differential pressure lines 24, 26 that are coupled on each side of the orifice plate 18.

Alternatively, the variable choke 20 can be automatically controlled using a pressure-operated device such as a diaphragm that is coupled to each side of the orifice plate 18.

The isolating valve 22 is used to control the flooding of the pipeline 12 and in particular is used to initiate the process of flooding the pipeline 12. The isolating valve 22 can be remotely operated by a control line (not shown) to the surface, or can be actuated by a diver or ROV.

The apparatus 10 optionally includes an injection pump 28 that is capable of injecting or pumping additive chemicals into the conduit 16 and thus the pipeline 12. The additive chemicals are typically stored in a reservoir 30, although it will be appreciated that a number of reservoirs 30 and/or pumps 28 may be used, depending on the particular chemicals (or other additives) that are to be added to the seawater. The injection pump 28 is driven from a high-pressure supply 32 through an injection control valve 34. The injection control valve 34 can control the flow of the injected chemicals according to the prevailing hydrostatic pressure, or at a flow rate that varies with the water flow rate into the pipeline 12 (e.g. to be approximately proportional to the amount of water flowing into the pipeline 12). The latter can be derived from a pressure differential across the orifice plate 18 *via* differential pressure lines 36, 38. Alternatively, the injection pump 28 can be driven from a system of fixed or variable orifices that can control the rate of adding of the chemicals.

The chemical additives contained in the reservoir 30 may be used, for example, to assist in detecting leaks during pressure testing and/or as a corrosion inhibitor.

It will be appreciated that the hydrostatic pressure difference diminishes as the pipeline 12 floods and the pressure between the interior of the pipeline 12 and the surrounding seawater will eventually equalise. At this point, the flooding of the pipeline 12 will cease. It is therefore useful to provide a means by which pressurised water can be admitted to the pipeline 12 to completely flood the pipeline 12 after the hydrostatic head has diminished. In the embodiment shown in Fig. 1, a boost pump 40 is provided that is operable *via* a remotely operated valve 42. The valve 42 is typically controlled *via* a control line 43 from the surface, or may be operated by a diver, ROV or AUV, but can be automatically actuated when a reduction in flow rate is detected (e.g. by use of differential pressure lines on each side of the orifice plate 18).

The boost pump 40 can be powered from the surface or preferably from a local power supply such as from the ROV, AUV or some other power supply (e.g. batteries, hydraulic power source etc). The boost pump 40 is preferably located downstream of the injection pump 28 so that chemicals may be added to the water used to flood the pipeline 12 (e.g. to assist in leak detection).

The conduit 16 can optionally include a one-way or check valve 45 to prevent the flow of water back towards the intake filter 14.

The apparatus 10 may include a pig (not shown) that is pumped along the pipeline 12 as it is being flooded. It is desirable to track the location of the pig within the pipeline 12 and this can be done using any conventional means (e.g. a telemetry system). Tracking the position of the pig allows the extent of flooding of the pipeline 12 to be monitored and controlled.

Additionally, it is advantageous to monitor the flow rate of the water into the pipeline 12 as it is being flooded. Thus, the apparatus 10 may include a flow recording device (not shown) such as a dial that can be read by an underwater camera provided on an ROV. The flow recording device can be of any conventional type, and can be electrically or otherwise coupled (e.g. *via* a telemetry system) to the surface for remote monitoring of the water flow rate.

Once the pipeline 12 has been flooded using the apparatus described above, it is then generally pressure tested to ensure that there are no fluid leaks.

Apparatus 10 includes a low-flow rate but high pressure pump 50 to pressure test the pipeline 12 so that the pressure, hydro or leak testing can follow the flooding of the pipeline 12 without the intervention of a support or surface vessel, or at least with less intervention than is common in the art.

Pump 50 is coupled to a conduit 52, the inlet of which is preferably coupled downstream of the injection pump 28 so that chemicals can be added to the water if required. The operation of pump 50 is controlled by a remotely operated valve 54 that can be operated *via* a control line 56 from the surface, or can be actuated by a diver, ROV or AUV. The valve 54 may be automatically operated after the flooding of the pipeline 12 is complete. An isolating valve 58 is located in the conduit 52 upstream of the pipeline 12 so that the conduit 52 can be opened and closed as required (e.g. to assist in leak detection). Operation of the isolating valve 58 may be automatic (e.g. actuated when the pump 50 is actuated) or may be remotely operated from the surface, or by a diver, ROV or AUV.

The pump 50 is actuated to provide a high-pressure flow of water, typically at a relatively low flow rate, into the pipeline 12. The high-pressure, low flow of water increases the pressure within the pipeline 12 so that any leaks or weak points in the pipeline 12 can be detected. Chemicals may be added to the water to facilitate identifying the source of any leaks.

Only a relatively low flow rate of water is required as the pipeline 12 is already filled with water and only the internal pressure within the pipeline 12 need be increased. The volume of water that enters the pipeline 12 during pressure testing can be considerably less than that required to flood it.

Referring now to Fig. 3 there is shown as an example a 12-inch (approximately 300 millimetre) bore pipeline 200 that is 5 kilometres long and has been laid on the seabed 202 between two installations 204, 206 in a deep-water field. Apparatus 10 is coupled to the pipeline 200 using a conduit 208 that is coupled to a pipeline inlet port, for example, provided at one end of the pipeline 200. Apparatus 10 is typically used to flood the pipeline 200 and can then be used to pressure test it in consecutive operations.

The flooding of the pipeline 200 typically requires a volume of water to fill the pipeline 200 (e.g. using the above described apparatus 10) that is in the order of 360 cubic metres. The additional volume of water required to raise the internal pressure of the pipeline 200 to around 700 bar (10150 psi) is 14½ cubic metres. This is only a small percentage (in the order of 4%) of the volume of water required to fill the pipeline 200 in the first instance, and highlights the difference in required capacity between a relatively low-pressure, high flow-rate flooding pump (e.g. boost pump 40) and a high-pressure, low-flow pressure testing pump (e.g. pump 50).

The pump 50 used for the pressure test typically requires to pressurise the pipeline 200 at approximately 1 bar per minute, and thus the required flow rate from pump 50 would be in the order of 21 litres per minute. If the pipeline 12 is to be pressured at around 3 bars per minute, then the corresponding flow rate is around 62 litres per minute.

Thus, the power required to provide these flow rates at the required pressures would reach a maximum as the final pressure is approached, and this maximum would be around 23 kilowatts (31 horse power) for the 1 bar per minute flow rate, and 60 kilowatts (94 horse power) for the 62 litres per minute flow rate.

Thus, the total energy required to pressurise the pipeline 200 during the pressure test is typically around 500 MJ. This energy can be provided by dropping an electrical cable from a supply or support vessel and coupling this to the pump 50. It will be appreciated that the pump 50 does not need to be actuated during the pressure test; it is only required to raise the internal pressure within the pipeline 12 to the required level. Thereafter, the isolating valves 22, 58 can be closed to retain the pressure within the pipeline 12 during the test.

Additionally, the vessel can leave the pump 50 *in situ* on the seabed during the pressure test (e.g. for a period of around 24 hours). However, a data logger would generally be required in the pipeline 12 so that data from the pressure test can be recorded and then up-loaded to the vessel upon its return. The vessel may return periodically to check the data.

It is preferred that the energy required to drive the pump 50 is provided locally (i.e. subsea) as this has the advantage that the surface vessel is not required to provide power for operating the pump 50. Thus, embodiments of the present invention provide the advantage that a smaller and cheaper vessel can be used that is provided with a suitable power supply for the pump (e.g. electric or hydraulic); the vessel does not require a pump and associated equipment on board.

The energy for pump 50 can be provided by a remotely operated vehicle (ROV) 210 that is coupled to apparatus 10 using an electrical cable 212. The ROV can be used to couple and de-couple the cable 212 as is known in the art.

Alternatively, the energy can be provided by a local (subsea) power supply such as a bank of suitable batteries. The batteries can be charged during flooding of the pipeline 200 by coupling an alternator or the like into the conduit 16 at an appropriate place so that the flow rate through the conduit 16 drives a turbine in the alternator that generates a sufficient current to charge the batteries.

It is preferred that the power to the pump 50 is provided locally so that there is no surface connection, although this may be possible in relatively shallow water or where there is access to a surface vessel. There is also the potential to use a smaller boat with less personnel and equipment as the pump used for pressure testing and the associated equipment would not be required on board the vessel; all that is required is an electrical cable or a hydraulic hose to be dropped to the seabed 202 for coupling to the apparatus 10 (e.g. by ROV 210).

As an alternative to using power from batteries or from an electrical cable from a surface vessel, the power for the pump 50 may also be provided by the ROV 210 or an autonomous vehicle (AUV - not shown). This would require the pump 50 to be provided with a suitable connector that can be engaged and disengaged by the ROV 210 or AUV so that power can be provided. Thus, the ROV 210 or AUV would be coupled to the pump 50 in any conventional manner to provide power thereto, and then de-coupled once the pressure test is complete. Indeed, the pump 50 may form a part of the ROV or AUV itself, and thus can be provided with electrical or hydraulic power therefrom.

Alternatively, the pump 50 may be pneumatically or hydraulically powered. For example, a hydraulic hose may be dropped from the surface vessel to provide hydraulic power to the pump 50. Alternatively, a suitable coupling can be used between the ROV or AUV to provide hydraulic or pneumatic power to the pump 50.

It will be appreciated that the above apparatus 10 has been described where the pump 50 forms a part of the apparatus 10, but it will also be appreciated that the pump 50 may be provided on a separate subsea skid to the remainder of the apparatus 10. Having the pump 50 included in a single subsea skid with the remainder of the apparatus 10 provides the advantage that only a single piece of equipment need be lowered to and retrieved from the seabed. Additionally, the apparatus 10 need only be coupled to the pipeline once in order to flood it and pressure test it. There is no requirement to couple and de-couple other equipment to the pipeline using an ROV for example. Both of these are significant advantages when the time taken to raise and lower the apparatus 10 is considered, and also the time taken to couple and de-couple conventional large-bore conduits.

Indeed, the pump 50 can be used independently of the remainder of the apparatus 10 that is generally used to flood the pipeline 12. The pump 50 can be provided on a separate subsea skid and coupled and de-coupled to the pipeline 12 using a diver, ROV or AUV as necessary. Additionally, the pump 50 may form a part of the ROV or AUV. Thus, the pump 50 does not have to be used with the remainder of the apparatus 10 described above, and could be used with other conventional methods of flooding the pipeline 12. However, it will be noted that combining the pump 50 with the remainder of the apparatus 10 has significant advantages in that the flooding and pressure testing of the pipeline 12 can be done in consecutive operations, without the intervention of a vessel, and without having to de-couple and couple other equipment and apparatus.

Referring now to Fig. 2, there is shown an alternative embodiment of apparatus 100 for flooding and pressure testing a pipeline 112. Apparatus 100 is similar to apparatus 10, and like numerals prefixed "1" have been used to designate like parts.

In the embodiment shown in Fig. 2, the pump 50 has been replaced by a gas accumulator bottle or a bank of such, generally designated 160, that is capable of providing high-pressure, low-flow gas into a reservoir 162 or other container of seawater. As the flow of gas from the accumulator bottles 160 (typically *via* a manifold (not shown) so that the gas flow rate can be controlled) enters the reservoir 162, the water therein is forced into the pipeline 112, preferably at high pressure and a low flow rate. The water already in the pipeline 112 is compressed, thus increasing the internal pressure to perform the pressure tests. This particular embodiment is advantageous as an electrical power supply is not required.

The gas bottles 160 can be filled with gas (e.g. air or the like) at the surface before the apparatus 100 is lowered to the seabed. A conduit 164 is coupled to the pipeline 112 so that the pressurised gas from the bottles 160 can enter the reservoir 162 and force pressurised water out of it and into the pipeline 112. A remotely-operated isolating valve 166 is coupled into the conduit 162 so that the flow of water into the pipeline 112 can be controlled from the surface (e.g. using a control line 168), or otherwise controlled (e.g. automatically in response to the pressure within the pipeline 112).

The gas bottles 160 may include a regulating device (not shown) to control the rate at which gas enters the reservoir 162 and also to control the pressure of the water from the reservoir 162 as it enters the pipeline 112. The regulating device can be of any conventional type, and could be a further remotely operated valve that can be controlled from the surface or by a diver, ROV or AUV, or automatically.

As with the previous embodiment, the gas accumulator bottles 160 may be provided on the same subsea skid as the remainder of the apparatus 100. Alternatively, the bottles 160 may be provided on a separate skid, or can form a part of the ROV or AUV.

Embodiments of the present invention provide numerous advantages over conventional apparatus for pressure testing pipelines. In particular, there is typically no requirement to use a support vessel at the surface with certain embodiments, thus saving significant costs in terms of manpower and the operation of the vessel, although this remains an option. In the event that power is required from a surface vessel, there is the potential to provide a smaller vessel at the surface with less personnel and less equipment on board the vessel, and this also has the potential to save on costs. Furthermore, the apparatus can be used to flood the pipeline and then to pressure test it in consecutive operations; there is no requirement to couple and de-couple various pumps and other apparatus and equipment to the pipeline in order to flood it and then pressure test it.

Certain embodiments of the present invention provide a subsea device that can be coupled to a previously flooded pipeline or facility to pressure test it.

Modifications and improvements may be made to the foregoing without departing from the scope of the present invention. For example, the apparatus and methods have been described in relation to subsea pipelines and installations, but they could be in any underwater environment, such as on a riverbed or lakebed.

CLAIMS

1. Apparatus for pressure testing a pipe or facility, the apparatus comprising an inlet having an opening (16, 116) to admit fluid into the pipe (12, 112) or facility (204, 206), a flow control device (20, 120) to control the flow rate of fluid into the pipe (12, 112) or facility (204, 206), and a subsea device (50, 160) to supply a pressurised fluid at high pressure into the pipe (12, 112) or facility (204, 206).

2. Apparatus according to claim 1, wherein the subsea device (50, 160) is capable of providing high pressures at low flow rates.

3. Apparatus according to either preceding claim, wherein the subsea device comprises a pump (50).

4. Apparatus according to claim 3, wherein the pump (50) is electrically operated.

5. Apparatus according to claim 3, wherein the pump (50) is hydraulically operated.

6. Apparatus according to any one of claims 3 to 5, wherein the pump (50) is supplied by a local power supply.

7. Apparatus according to claim 6, wherein the local power supply comprises one or more batteries.

8. Apparatus according to claim 7, wherein the or each battery is charged using an alternator coupled into the inlet (16, 116).

9. Apparatus according to claim 6, wherein the local power supply comprises an electrical, hydraulic or pneumatic power supply from a remotely operated vehicle (210) or autonomous vehicle.

10. Apparatus according to claim 1 or claim 2, wherein the subsea device comprises one or more gas bottles (160).

11. Apparatus according to claim 10, wherein the or each bottle (160) is capable of providing a high-pressure, low-flow gas into a reservoir (162) or other container of fluids.

12. Apparatus according to claim 11, wherein the or each gas bottle (160) admits pressurised gas into the reservoir (162) and forces pressurised fluid into the pipe (12, 112) or facility (204, 206) that is being pressure tested.

13. Apparatus according to any preceding claim, wherein the inlet (16, 116) is coupled to the pipe (12, 112) *via* a pipe inlet port.

14. Apparatus according to any preceding claim, wherein the apparatus includes a flow-recording device for measuring and/or recording the flow of

fluid entering the pipe (12, 112) or facility (204, 206).

15. Apparatus according to any preceding claim, wherein the flow control device comprises a variable opening valve (20, 120) that can maintain a substantially constant flow of fluid into the pipe (12, 112) or facility (204, 206).

16. Apparatus according to any preceding claim, wherein the inlet (16, 116) contains a filter (14, 114) that can be used to filter or strain the fluid that is admitted into the pipe (12, 112) or facility (204, 206).

17. Apparatus according to any preceding claim, wherein the apparatus includes a chemical injection device (28, 128) for injecting chemicals into the fluid entering the pipe (12, 112) or facility (204, 206).

18. Apparatus for pressure testing a subsea pipe or facility, the apparatus comprising a subsea device (50, 160) for introducing a pressurised fluid into the pipe (12, 112) or facility (204, 206) at high pressure.

19. Apparatus according to claim 18, wherein the subsea device (50, 160) is capable of providing high pressures at low flow rates.

20. Apparatus according to claim 18 or claim 19, wherein the subsea device comprises a pump (50).

21. Apparatus according to claim 20, wherein the pump (50) is supplied by a local power supply.

22. Apparatus according to claim 21, wherein the local power supply comprises one or more batteries.

23. Apparatus according to claim 22, wherein the or each battery is charged using an alternator.

24. Apparatus according to claim 21, wherein the local power supply comprises an electrical, hydraulic or pneumatic power supply from a remotely operated vehicle (210) or autonomous vehicle.

25. Apparatus according to claim 18 or claim 19, wherein the subsea device comprises one or more gas bottles (160).

26. Apparatus according to claim 25, wherein the or each bottle (160) is capable of providing a high-pressure, low-flow gas into a reservoir (162) or other container of fluids.

27. Apparatus according to claim 26, wherein the or each gas bottle (160) admits pressurised gas into the reservoir (162) and forces pressurised fluid into the pipe (12, 112) or facility (204, 206) that is being pressure tested.

28. A method of pressure testing a pipe or facility, the method comprising the steps of admitting fluid into the pipe (12, 112) or facility to flood it, introducing a pressurised fluid into the pipe (12, 112) or facility (204, 206), and monitoring the retention of fluid within the pipe (12, 112) or facility (204, 206).

29. A method according to claim 28, wherein the method includes the additional step of providing a subsea device (50, 160) to introduce the pressurised fluid).

30. A method according to claim 29, wherein the method includes the additional step of coupling the subsea device (50, 160) to the pipe (12, 112) or facility (204, 206).

31. A method according to any one of claims 29 to 30, the step of admitting fluid into the pipe (12, 112) or facility (204, 206) involves opening an isolating valve (58, 166) to allow fluid to flow into the pipe (12, 112) or facility (204, 206) under the head of water above the pipe (12, 112) or facility (204, 206).

32. A method according to any one of claims 29 to 31, wherein the step of introducing a pressurised fluid into the pipe (12, 112) or facility (204, 206) involves the step of actuating the subsea device (50, 160).

33. A method according to any one of claims 28 to 32, wherein the method includes the additional step of filtering the fluid that enters the pipe (12, 112) or facility (204, 206).

34. A method according to any one of claims 28 to 33, wherein the method includes the additional step of adding chemicals to the fluid that enters the pipe (12, 112) or facility (204, 206).

35. A method of pressure testing a subsea pipe or facility, the method comprising the step of actuating a subsea device (50, 160) to introduce a pressurised fluid into the pipe (12, 112) or facility (204, 206) at high pressure.

36. A method according to claim 35, wherein the method includes the additional step of coupling the subsea device (50, 160) to the pipe (12, 112) or facility (204, 206).

37. A method according to claim 35 or claim 36, wherein the step of actuating the subsea device (50, 160) comprises providing power to the device (50, 160).

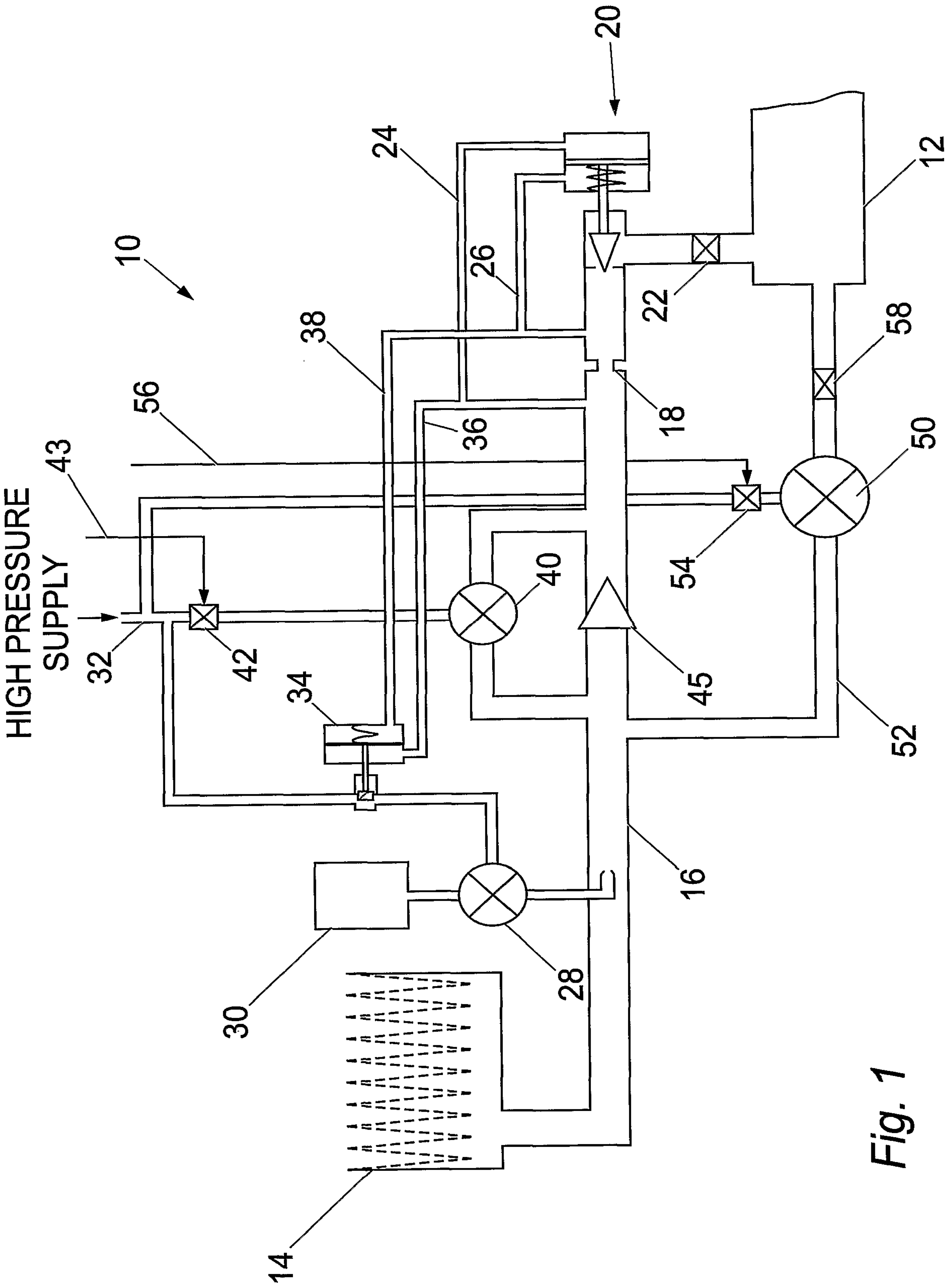
38. A method according to claim 37, wherein the power can be electrical, hydraulic or pneumatic.

39. A method according to claim 37 or claim 38, wherein the method includes the additional step of

coupling a remotely operated vehicle (210) or autonomous vehicle to the subsea device (50, 160).

40. A method according to any one of claims 35 to 39, wherein the method includes the additional step of filtering the fluid that enters the pipe (12, 112) or facility (204, 206).

41. A method according to any one of claims 35 to 40, wherein the method includes the additional step of adding chemicals to the fluid that enters the pipe (12, 112) or facility (204, 206).



HIGH PRESSURE
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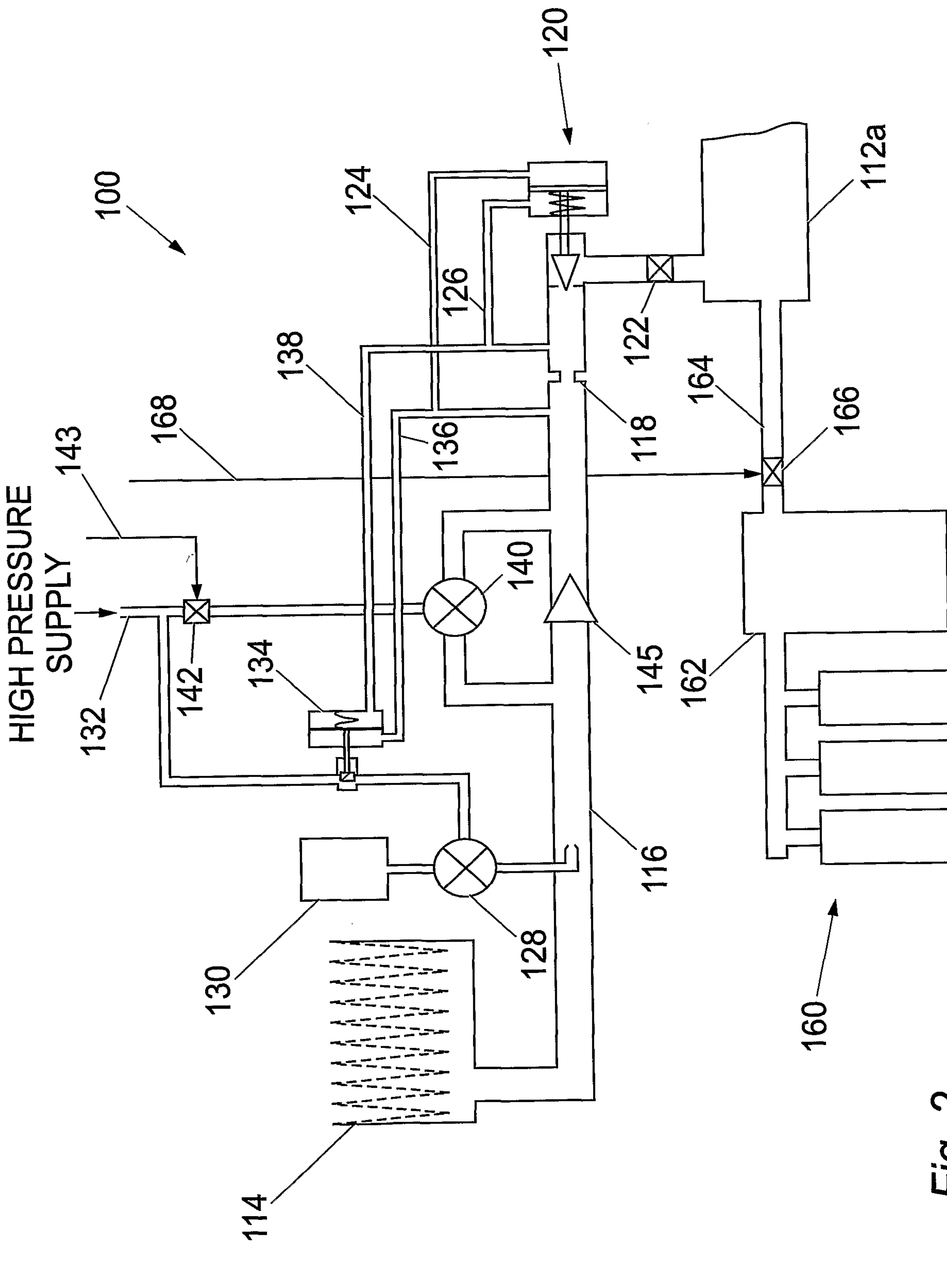
Fig. 1



HIGH PRESSURE SUPPLY
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Fig. 2

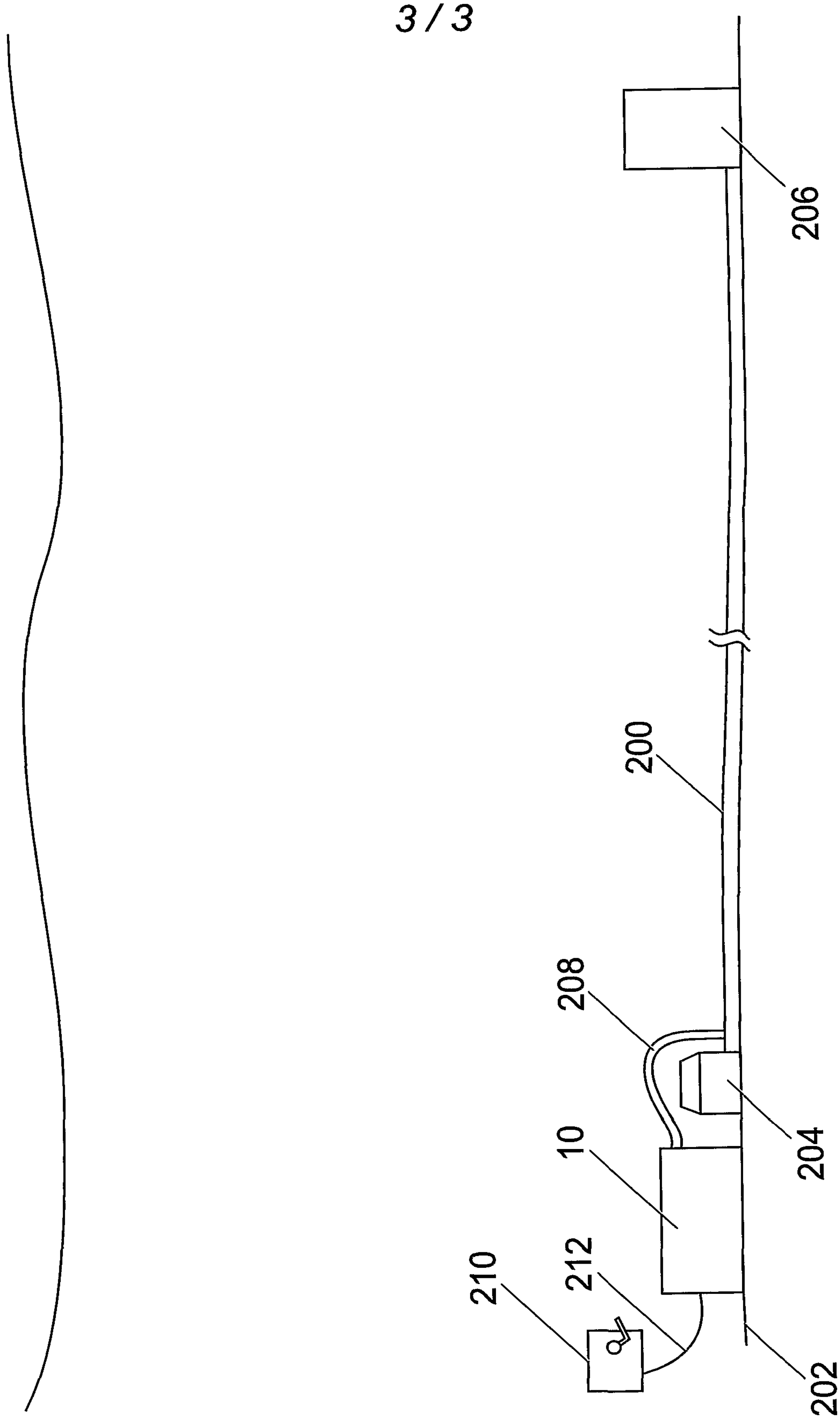

Fig. 3

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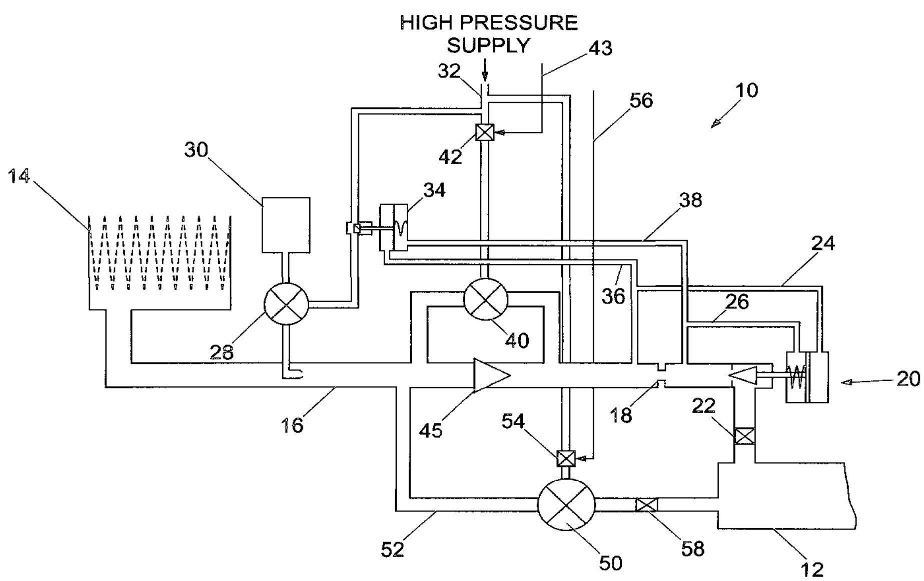
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** APPARATUS FOR AND METHOD OF FLOODING AND/OR PRESSURE TESTING PIPELINES



(57) **Abstract:** Apparatus for and methods of flooding and/or pressure testing a pipe (12) or facility, wherein a subsea device (50) is used to pressure test the pipe (12) once flooded. The subsea device is typically a pump (50) that is located subsea, and preferably supplied from a local power supply (e.g. batteries, ROV, AUV etc). Certain embodiments allow the pipe (12) to be flooded and then pressure tested in consecutive operations without having to de-couple and/or couple additional apparatus to the pipe (12).

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INTERNATIONAL SEARCH REPORT

PCT/GB 02/01997

A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 927 901 A (GRAVES LESLIE JOHN) 27 July 1999 (1999-07-27) claims 1-29	1-6,9-21 28
Y	US 4 267 857 A (VAN HAAFTEN HENRY M T) 19 May 1981 (1981-05-19) claims 1-37	28
A	US 6 082 182 A (MARESCA JR JOSEPH W ET AL) 4 July 2000 (2000-07-04) claims 1-12	1
A	US 5 375 455 A (MARESCA JR JOSEPH W ET AL) 27 December 1994 (1994-12-27) claims 1-21	1

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[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2003	20/10/2003

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 589 434 A (KELLEY BRUCE T) 20 May 1986 (1986-05-20) claims 29-43	28-41
A	WO 93 14382 A (GUDMUNDSSON JON STEINAR) 22 July 1993 (1993-07-22) page 11 - page 12	28-41
A	US 4 758 117 A (MAKI YUNOSUKE ET AL) 19 July 1988 (1988-07-19) column 2 - column 5	28

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INTERNATIONAL SEARCH REPORT

Information on patent family members

PCT/GB 02/01997

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5927901	A	27-07-1999	AU	3933197 A	22-04-1999
			BR	9603176 A	09-09-1997
			GB	2303895 A ,B	05-03-1997
			NO	963137 A	29-01-1997
US 4267857	A	19-05-1981	NONE		
US 6082182	A	04-07-2000	US	5948969 A	07-09-1999
US 5375455	A	27-12-1994	US	5189904 A	02-03-1993
			AU	7315694 A	20-02-1995
			WO	9503535 A1	02-02-1995
			US	5415033 A	16-05-1995
US 4589434	A	20-05-1986	AU	575483 B2	28-07-1988
			AU	5754386 A	18-12-1986
			BR	8602490 A	27-01-1987
			CA	1236753 A1	17-05-1988
			GB	2177372 A ,B	21-01-1987
			NO	861402 A ,B,	11-12-1986
WO 9314382	A	22-07-1993	NO	920155 A	14-07-1993
			WO	9314382 A1	22-07-1993
US 4758117	A	19-07-1988	JP	1886035 C	22-11-1994
			JP	6014786 B	23-02-1994
			JP	61157269 A	16-07-1986